Spatial-Temporal and Spectral Aspects of Forest Disturbance

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Position on selected questions:

1) ***What kinds of spatial-temporal questions are of interest?***

Our work with spatial temporal data sets focuses on land cover change and its drivers. Specifically we are interested in the occurrence, type and extent of forest disturbances in the boreal biome. Disturbance occurrence and recovery have important implications for carbon balance and human habitation issues. In the past we have explored analysis of RS images using fractals, lacunarity and other spatial descriptors. We have even used 3-D radar remote sensing model to examine expected backscatter response of imposed spatial patterns (Sun and Ranson 1998). This work will lead, ultimately, to a rapid assessment of forest change and understanding of the forces driving these changes.

For example we wish to classify areas with lower dry biomass (naturally or human disturbed areas) based on the radar backscattering properties and spatial texture, then characterize the spatial pattern using fractal analysis. We classified radar images into low biomass categories both natural, poorly drained sites, bogs, and anthropogenic, thinned areas, clear cuts and regeneration (Fig. 1).

The radar images used were AIRSAR P, L, and C bands. The channels with best separabilities between categories were selected in classification. The texture features from the PWF (polarimetric whitening filter) filtered AIRSAR images were also used in classification. The texture was an index, i.e. the differences of the Fourier spectral power at frequency zero and one. Bayesian classifier was used, and the results were verified using airphotos.

Knowledge of the locations and types of low biomass areas is useful for forest inventory purposes. Also of interest is quantifiable information regarding spatial characteristics of the polygons of patches classified as each of the categories. The fractal dimension determined from the slope of the regression relationship between patch perimeters and areas has been shown to be an indicator of the type of processes acting upon the landscape (Turner and Gardner, 1991). The following table summarizes the fractal dimensions for different categories. Bog and regeneration have smaller fractal dimensions, indicating smoother shaped patches. The small differences between D_{avg} and D_l of these two categories suggest that the relationship persists across the scale being examined. The larger differences between D_{avg} and D_l for other categories indicate a change in the perimeter-area relationship with scale. The large values of D_l for thinned, opening and clearcut also suggest that the perimeters of the largest patches are very irregular and contorted.

Table 1. **Spatial characteristics of landcover patches**.
Fraction –fractional image area occupied by the category;
S_{max} - area of the largest patch; P_{max} - longest patch perimeter;
D_{avg} - fractal dimension derived using all patches larger than 1 pixel; D_l -fractal dimension derived using patches for 25 largest sizes.

Class	Fraction(%)	S_{max}	P_{max}	Numbers	D_{avg}	D_l
Thinned	7.1	121	166	1404	1.44	1.82
Opening	11.3	533	530	1652	1.43	1.72
Clear Cut	7.7	2186	1496	273	1.40	1.63
Regeneration	1.7	651	396	202	1.33	1.38
Bog	0.6	446	282	41	1.32	1.34

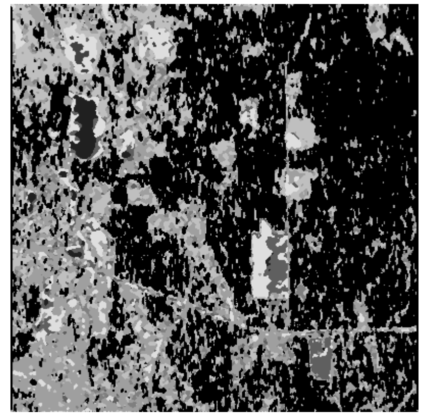

Fig. 1. Classification from SAR images. The dark area is undisturbed forest.

2) ***Which types of data mining techniques are useful?***

Forest management practices, such as thinning, strip or clear cutting, and natural processes, such as tree-fall by forest fire, windthrow, and insect damage change the forest canopy structure by creating gaps at different scales. A gap may be defined as the land surface area directly under a canopy opening. The fraction of total land area involved in such disturbances is an important ecosystem parameter, affecting overall species compositions, vegetation dynamics and stand structure. Forest response to regionally dominant disturbance regimes leads to diverse landscapes. Depending on the scale of observations, gap size and spatial clustering of trees will have varying influence on measured forest parameters, such as stem density and biomass. Gaps represent both the forest response to disturbance and the means to regeneration and succession

Knowledge of radar (or other remote sensor) response to gap frequency and size distribution will provide important links between radar images and disturbance regime, forest dynamics, and biomass. This knowledge is also necessary because these effects may significantly confuse interpretation of other forest parameters. From a resource perspective, forest gaps reflect forest dynamics and disturbance regime, which are important for biomass appraisal. From a radar perspective, gaps ranging from sub-pixel to multi-pixel scale may have major impacts on radar returns.

Theoretical radar backscatter models can be useful tools in the development of connecting models between the radar observations and forest ecosystem models. The radar textural information resulting from forest heterogeneity was explored using both radar backscatter model and AIRSAR imagery (Weishampel, et al., 1994). A spatially explicit radar backscatter model developed at Goddard Space Flight Center (Sun and Ranson, 1995) can be used to investigate the sensitivity of radar to uneven distribution of trees and associated gaps.

A 3-D radar backscatter model was used to simulate forest stands with different spatial patterns (Sun and Ranson, 1998). Theoretical simulations of two forest stands with the same trees (biomass) and the same forest floor conditions, but random or clumped tree positions show that the averaged backscattering from the two stands were very similar and the differences are well within the accuracies of radar image calibration. The gaps and tree clumping can be identified from the spatial patterns using lacunarity (Henebry and Kux, 1995) analysis of the two images. The spatial pattern analysis also showed that the effects of tree clumping on radar backscattering may be insignificant when image resolution is coarser than 30 meters for the cases simulated in this study. The binary quartile images show more lacunarity differences between random and clumped stands than the radar backscattering image itself does. In addition, various strip cuts that occur in our Maine forest study area were simulated, and the backscattering intensity and spatial characteristics of simulated radar signatures were compared with similar targets in AIRSAR images.

A 3-D lidar model was recently published that incorporates similar forest structure to that used in radar model (Sun and Ranson, 2000).

We are also trying to exploit sensor fusion for our purposes (Ranson et al., 2002). One activity is to combine MODIS and Radarsat for mapping landcover and disturbance over large areas of Siberia. We found Radarsat to be of limited use as Chh backscatter data, but were able to gain added information through the use of texture measures (Fig. 2).

A data mining technique is the application of these texture measures (such as homogeneity, contrast, dissimilarity, mean, variance and entropy) to radar data at different window sizes. Texture is one of the important characteristics used to identify objects in an image. Textural features contain information about the spatial distribution of tonal variations within a band, unlike spectral features, which describe the average tonal variation in the various bands of an image.

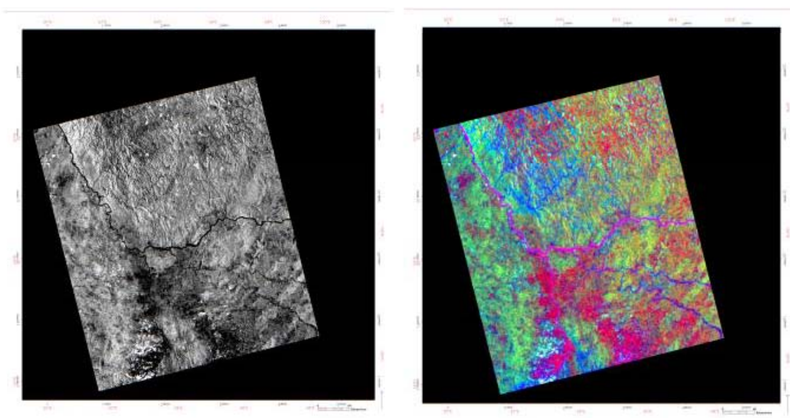

Fig.2. Left - Radarsat SWB image over Central Siberia (8/1/2000) after 5x5 filtering. Right- Color composite of texture measures extracted from the same mage at 11 by 11 window size. Red – Homogeneity, Green – Mean, Blue – Variance.

5). ***How should querying a spatio-temporal vs. spatio-spectral vs. spectral-temporal slices from image time series be handled?***

Each pixel in a spatial database would be represented as a multi-dimensional structure. The spatial component of the structure would describe the location of the pixel (i,j). Other components of this structure could be spectral (band 1, band 2… band n), temporal (t1, t2, ..tn), textural (tx1, tx2, …tx n). Complex queries could be written to identify areas with a series of specific characteristics based on relevant expertise domains. The different components of a group of structures could be displayed graphically in two or three dimensions, as a plot or as an image. The temporal context of a spatial unit could also be extracted by generating measures that describe the amount of spectral or textural change taking place at one location at different times.

Understanding the temporal context of a spatial unit (a pixel and/or an area) is especially useful when dealing with different phenomena that have different rates of onset. In the case of disturbance monitoring, the rapid onset of a forest fire or a logging would have one type of temporal signature, where the more gradual onset of forest decline due to insect infestation or pollution would have another. The same applies to rates of recovery: a logged area that is replanted with seedlings would exhibit more rapid change from one state to another than the site of a ground fire where the soils became mineralized.

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